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EP 0643221 A1 WO 94/27041 A1 WO 92/12341 A1
US 5577479 A US 5456233 A US 5213084 A

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(54) Fuel supply system for solenoid-actuated fuel injectors

(57) A fuel pump 10 supplies fuel via a non-return valve 12 to an accumulator 14 which can be connected to an injector supply line 18 by a three-way valve 16. The valve 16 and the solenoid actuators 22 of the injectors 20 are controlled by a controller 24. In operation, starting from the position shown, the injectors are closed and the three-way valve 16 connects the supply line 18 with drain 26 to reduce the safety risk of having a supply line continuously at high pressure, and also to reduce the risk of fuel being delivered to a leaky injector. To start injection, the three-way valve is moved to connect the supply line 18 to the accumulator 14 then the actuators 22 are energised to open the injectors. To terminate injection, the injectors are closed then the valve 16 is moved to again reduce the pressure in the supply line 18. The pump 10, valves 12,16 and accumulator 14 may be in a single body 32. A distributor (34, fig .2) may be provided between the three-way valve 16 and the injectors 20.

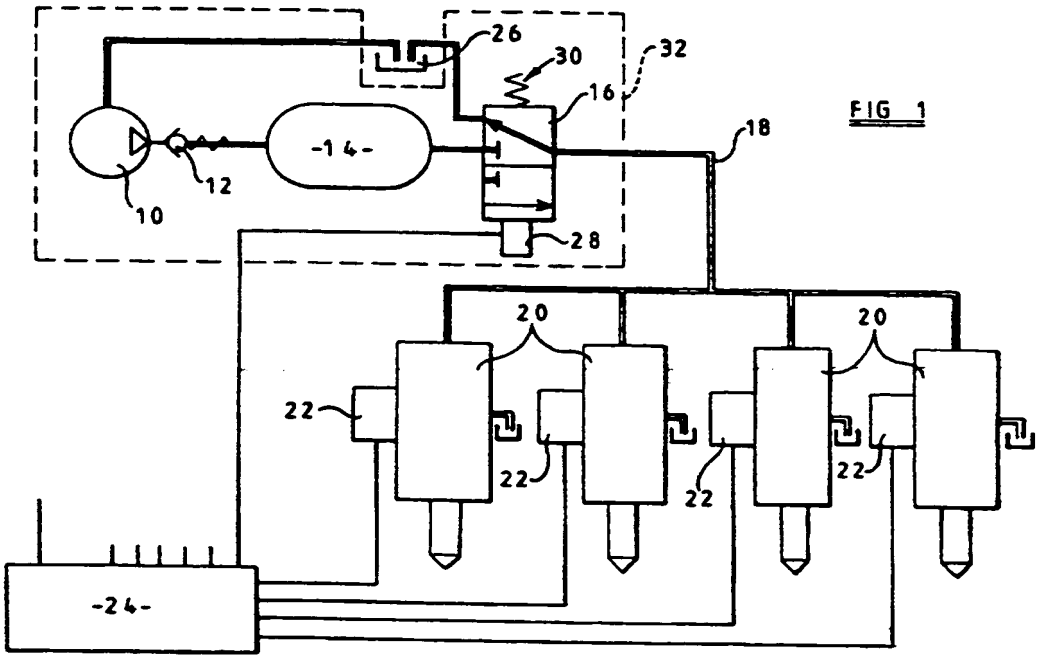

FIG 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1995

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FIG 1

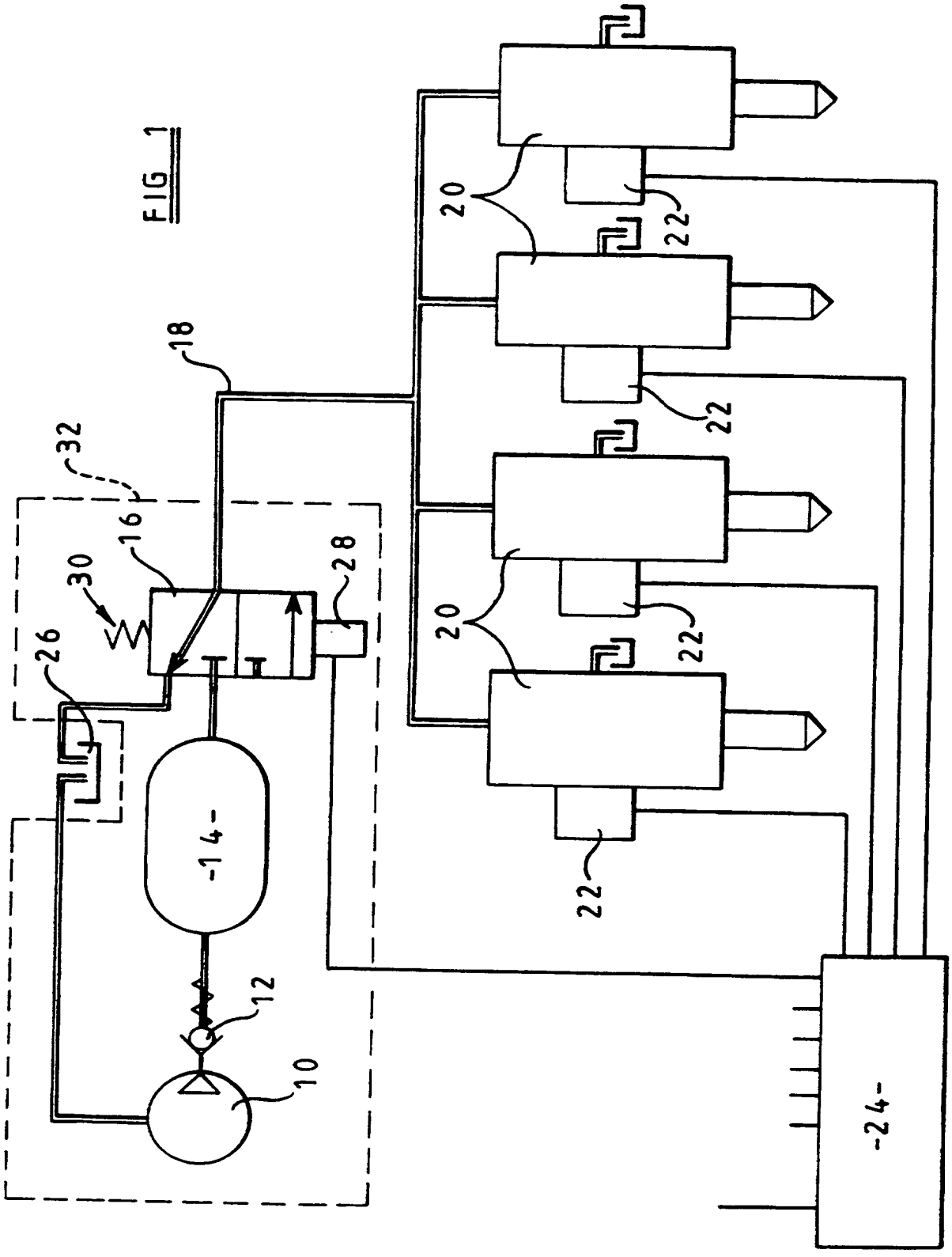
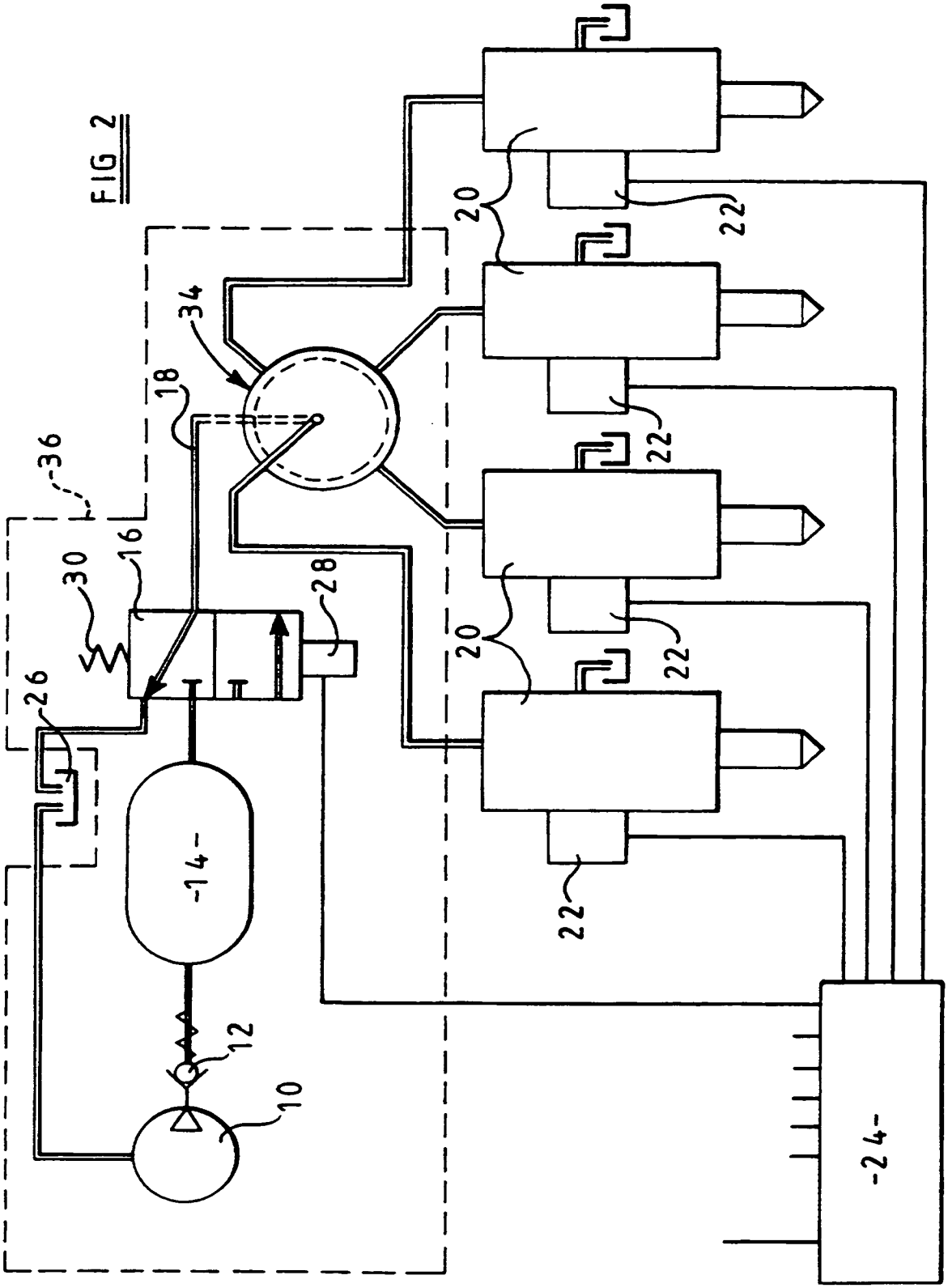


FIG 2



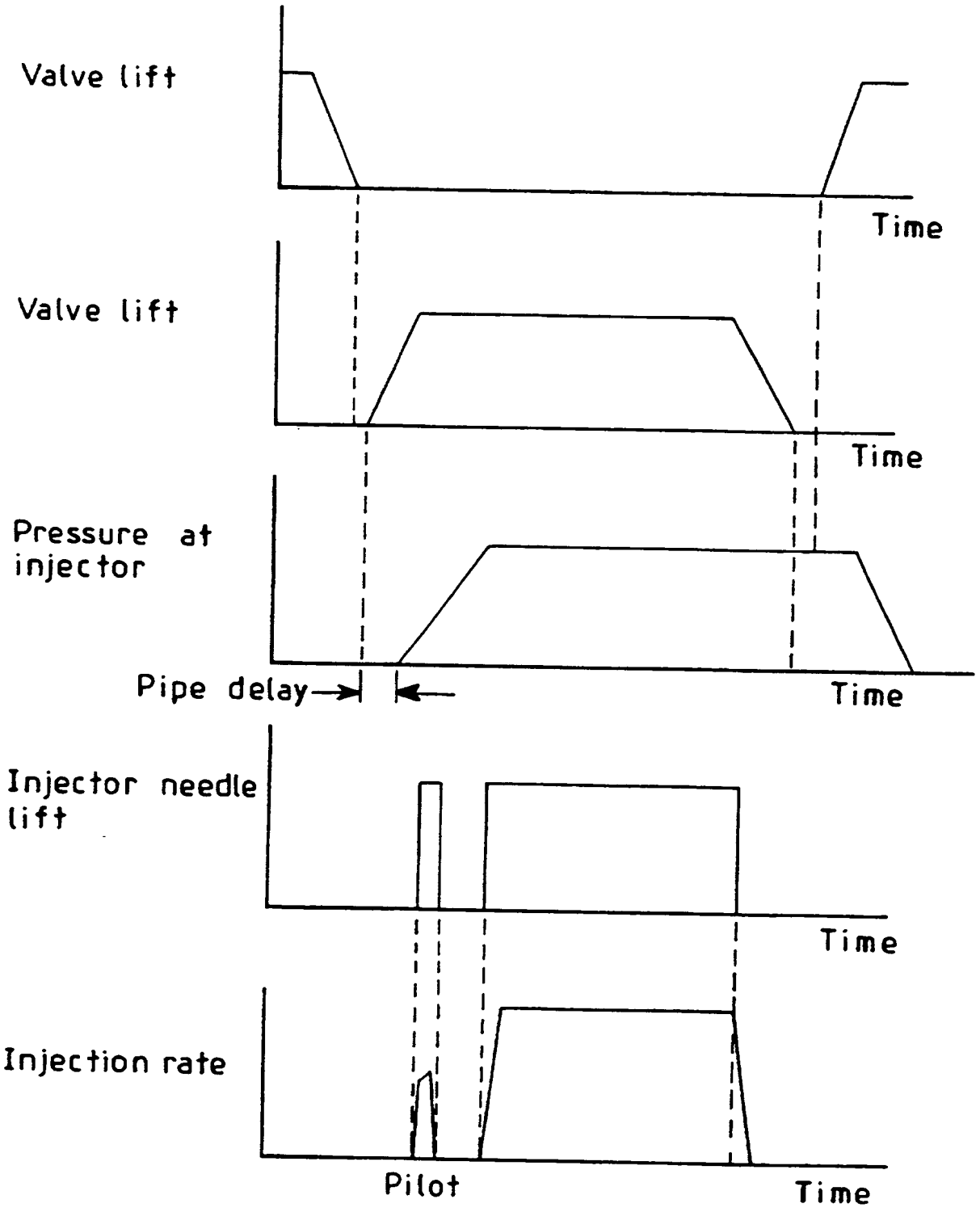

Valve lift
Time
Valve lift
Time
Pressure at injector
Pipe delay
Time
Injector needle lift
Time
Injection rate
Pilot
Time

FIG 3

FUEL SYSTEM

This invention relates to a fuel system for use in supplying fuel at high pressure to the cylinders of an internal combustion system.

In order to permit fuel to be supplied at a pressure substantially independent of engine speed, an accumulator type fuel system may be used. Such a system includes an accumulator which is arranged to be charged with fuel by a suitable fuel pump. The accumulator is connected to a three-way valve, a common outlet of which is connected to a distributor arrangement. The distributor arrangement controls the distribution of fuel so that fuel is delivered to a plurality of fuel pressure actuable injectors, in turn. The three-way valve is also connected to a spill or low pressure drain arranged to permit fuel to flow away from the injectors thereby lowering the fuel pressure exerted on the injectors.

In use, in order to commence injection, the three-way valve is actuated to permit fuel to flow from the accumulator to one of the injectors as determined by the distributor arrangement. The application of high pressure fuel to that injector results in the injector opening, and hence in fuel being delivered through that injector. In order to terminate injection, the three-way valve is actuated to break the communication with the accumulator, and instead to permit communication between the common outlet and the spill or drain. Such communication results in a reduction in the pressure applied to the injector and subsequently in the injector closing. After termination of injection, the distributor arrangement breaks communication between the injector and the three-way valve, instead connecting a different injector to the three-way valve to enable subsequent fuel delivery through that injector.

The timing of commencement and termination of injection is controlled by the three-way valve, and it has been found that it is difficult to obtain adequate performance of the three-way valve to permit such timing to be controlled sufficiently quickly to permit short injection periods.

Instead of the above described accumulator type system, a common rail fuel system has been used. Such a system includes a plurality of solenoid controlled injectors connected to a supply line which is maintained at high pressure by a suitable pump, perhaps in combination with an accumulator. In such an arrangement, in order to obtain fuel injection through a particular injector, that injector is opened under the control of its solenoid actuator, termination of injection similarly being controlled by the solenoid actuator. A number of different types of injector are available, some being arranged to be opened by a solenoid and closed under the action of a spring, others opening under the action of a spring when a solenoid is de-energized, and closing when the solenoid is energized.

The common rail systems have the disadvantage that, in use, the supply line to each of the injectors is continuously at high pressure and thus presents a safety hazard. Further, if the injectors leak slightly, the engine may not satisfy emission regulations.

It is an objection of the invention to provide a fuel system in which the disadvantages described hereinbefore are reduced.

According to the present invention there is provided a fuel system comprising a source of fuel at high pressure, a supply line for supplying fuel from the source to a plurality of solenoid actuable injectors, and

valve means arranged to permit the pressure of fuel within the supply line, in use, to be reduced.

The fuel system may further comprise a distributor arrangement provided in the supply line such that fuel from the source is supplied to the injectors, in turn, in use.

The invention will further be described, by way of example, with reference to the accompanying drawings in which like references denote like parts, and in which:-

Figure 1 is a diagrammatic view of a fuel system in accordance with a first embodiment;

Figure 2 is a diagrammatic view of a fuel system in accordance with a second embodiment; and

Figure 3 is a series of simplified diagrams illustrating the operation of the first and second embodiments.

The fuel system illustrated in Figure 1 comprises a fuel pump 10 of conventional form which is arranged to supply fuel through a non-return valve 12 to an accumulator 14. The outlet of the accumulator 14 is connected to a three-way valve 16 which includes a common port connected to a supply line 18. The supply line 18 is arranged to supply fuel to a plurality of solenoid actuable injectors 20 of known form.

The solenoid actuator 22 of each of the injectors 20 is controlled by a controller 24. The controller 24 further controls operation of the three-way valve 16.

The three-way valve 16 further includes an outlet which is connected to a suitable spill or drain arrangement 26 arranged such that when the three-way valve 16 permits communication between the supply line 18 and the spill or drain arrangement 26, the pressure of fuel within the supply line 18 is reduced.

In use, starting from the position illustrated in Figure 1, the controller 24 is controlling the solenoid actuator 22 of each of the injectors 20 so that each of the injectors 20 is closed. The three-way valve 16 is positioned so as to permit communication between the supply line 18 and the spill or drain arrangement 26 thus permitting the pressure of fuel within the supply line 18 to be reduced, and hence reducing the safety risk of having a supply line continuously at high pressure. The reduction in the pressure of the supply line 18 further reduces the risk of fuel being delivered through any of the injectors 10 should the injectors 20 be slightly leaky.

When it is desired to commence injection, the solenoid actuator 28 of the three-way valve 16 is actuated by the controller 24 to move the three-way valve 16 against the action of the spring 30 to a position in which the accumulator 14 communicates with the supply line 18, the communication between the supply line 18 and the spill or drain arrangement 26 being broken. Once such communication has been achieved between the accumulator 14 and the supply line 18, the controller 24 then actuates the solenoid actuator 22 of whichever one of

the injectors 20 through which injection is desired. Since fuel at high pressure is supplied through the supply line 18 to each of the injectors 20, the actuation of the solenoid actuator 22 of one of the injectors 20 results in that injector 20 opening and in fuel being supplied from the supply line 18 through that injector 20 to the associated cylinder of an engine.

When injection is to be terminated, the solenoid actuator 22 of the injector 20 which is open is controlled by the controller 24 to close the injector 20. Once injection has been terminated, the controller 24 controls the solenoid actuator 28 of the three-way valve 16 to permit the valve 16 to be returned to the position illustrated in Figure 1, and once that position has been reached, fuel is permitted to flow from the supply line 18 through the three-way valve 16 to the spill or drain arrangement 26 thus once more reducing the pressure of fuel within the supply line 18.

Although the fuel pump 10, non-return valve 12, accumulator 14 and three-way valve 16 have been described hereinbefore as separate items, these items could be included in a single body as denoted by the dashed line 32 in Figure 1.

The arrangement illustrated in Figure 2 is similar to that illustrated in Figure 1 with the exception that an engine driven rotary distributor arrangement 34 is provided in the supply line 18, the distributor arrangement 34 being arranged to permit communication through the supply line 18 between the three-way valve 16 and only one of the injectors 20 at any particular time.

In use, starting from the position illustrated in Figure 2, each of the injectors 20 is closed and the supply line 18 is connected through the three-way valve 16 with the spill or drain arrangement 26 thus the supply line 18 is at relatively low pressure. The distributor arrangement 34 has been moved to a position in which the left-hand most injector 20 as illustrated in Figure 2 communicates through the supply line 18 and distributor arrangement 34 with the three-way valve 16.

In order to commence injection, the three-way valve 16 is moved under the control of the controller 24 to a position in which the communication between the supply line 18 and spill or drain arrangement 26 is broken and instead the supply line 18 communicates with the accumulator 14. Once such communication has been achieved, the solenoid actuator 22 of the left-hand most injector 20 is operated under the control of the controller 24 to open the left-hand most injector 20 to permit fuel to be delivered therethrough.

In order to terminate injection, the solenoid actuator 22 of the open injector 20 is controlled to close the injector 20 and thus terminate the flow of fuel through the injector 20. Once injection has terminated, the three-way valve 16 is returned to the position illustrated in Figure 2 under the control of the controller 24 thus permitting the supply line 18 to communicate with the spill or drain arrangement 26 to reduce the fuel pressure in both of the part of the supply line 18 between the three-way valve 16 and the distributor arrangement 34 and the part of the supply line 18 between the distributor arrangement 34 and the left-hand most injector 20. The distributor arrangement 34 is then controlled to permit communication between the three-way valve 16 and a different one of the injectors 20, whereafter in order to commence injection through that

injector, the three-way valve 16 is switched as described hereinbefore and the solenoid actuator 22 of that injector 20 is controlled to commence injection through that injector 20.

As in the case in Figure 1, the fuel pump 10, non-return valve 12, accumulator 14, three-way valve 16, and distributor arrangement 34 may be separate items or may be combined into a single unit as denoted by the dashed line 36 in Figure 2. Further, the three-way valve 16 and distributor arrangement 34 could be combined to form a single unit separate from the fuel pump 10 and accumulator 14.

Although a rotary distributor arrangement 34 is used in the illustrated embodiment, any other suitable type of distributor arrangement could be used.

The diagrams in Figure 3 illustrate the operation of both the embodiment of Figure 1 and that of Figure 2. The top part of the diagram illustrates the operation of the part of the three-way valve 16 controlling communication between the supply line 18 and the spill or drain arrangement 26 as denoted by the upper part of the three-way valve 16 in Figures 1 and 2, the second diagram of Figure 3 illustrating the operation of the other part of the valve 16. The rates of movement of the valve, either when opening or closing are relatively unimportant, but it will be noticed from the top two parts of the diagrams of Figure 3 that at no time does the control valve 16 permit communication directly between the accumulator 14 and the spill or drain arrangement 26. Depending upon the type of three-way valve 16 used, there may be times that which such flow is possible, but clearly it is undesirable.

The third diagram of Figure 3 illustrates the pressure at the injectors, or in the case of Figure 2, the injector selected by the distributor arrangement 34. It will be noted that the pressure at the injector starts to rise after the part of the three-way valve 16 which controls communication between the supply line 18 and the accumulator 14 is opened, such a delay being a result of the pressure wave front having to travel along the supply line 18. Once the pressure at the injector has started to rise, the controller 24 operates the actuator 22 of that injector to open that injector, and the fourth diagram of Figure 3 illustrates the position of the injector needle. As illustrated, the injector needle is arranged to be lifted from its seating for a short period of time, to return into engagement with its seating, and subsequently to be lifted from its seating once more. Such movement of the needle of the injector results in a short, pilot injection of fuel followed by a main injection, and in fuel being delivered to the cylinder associated with that injector at the injection rates illustrated in the final diagram of Figure 3. As the pilot injection is timed to occur whilst the pressure at the injector is still rising, the pilot injection is at a pressure lower than the main injection. However, if desired, the pilot and main injections can both be timed to occur whilst the pressure at the injector is at its maximum level by adjusting the time at which the three-way valve 16 is switched to permit communication between the accumulator 14 and the supply line 18.

As the timing of injection and termination of injection are not controlled directly by the three-way valve 16, any restriction to the flow of fuel due to the presence of the three-way valve 16 and, for example, due to the supply line 18 being of relatively restricted diameter, do not significantly affect the ability to accurately control the timing of injection and termination of injection. In order to maximize efficiency, it is desirable

to minimize the quantity of fuel which has to be pressurized by the flow of fuel from the accumulator, on operation of the valve 16. This is better achieved by the embodiment of Figure 2 than that of Figure 1, and may further be achieved by using a line of relatively small cross-sectional area for the line 18.

Although not illustrated, a suitable line conditioning valve may be provided in the line 18 in order to retain fuel within the line 18, maintaining the line pressure at a level greater than a predetermined, relatively low level, when the valve 16 is arranged to reduce the pressure within the line 18, and hence prevent the formation of cavities therein, whilst permitting a substantially unrestricted flow of fuel along the line 18 when the line 18 communicates with the accumulator 14.

CLAIMS

1. A fuel system comprising a source of fuel at high pressure, a supply line for supplying fuel from the source to a plurality of solenoid actuable injectors, and valve means arranged to permit the fuel pressure within the supply line, in use, to be reduced.

2. A fuel system as claimed in Claim 1, wherein the supply line is in constant communication with each of the injectors.

3. A fuel system as claimed in Claim 1, further comprising a distributor arrangement whereby the supply line communicates with the injectors in turn.

4. A fuel system substantially as hereinbefore described with reference to Figures 1 and 3 or Figures 2 and 3 of the accompanying drawings.

The Patent Office

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Application No: GB 9604693.3 **Examiner:** John Twin
Claims searched: 1-4 **Date of search:** 16 April 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F1B (B2JB, B2JCP)

Int Cl (Ed.6): F02M 41/16, 59/36, 59/44, 63/00

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 643221 A1	(Lucas)	1,3
X	WO 94/27041 A1	(Cummins) - note control valve 20	1,2
X	WO 92/12341 A1	(Nippondenso) - see abstract	1,2
A	US 5577479	(Robert Bosch)	
X	US 5456233	(Robert Bosch) - see eg col.3, lines 44-64	1,2
X	US 5213084	(Robert Bosch) - see eg fig.1; col.2, line 57 to col.3, line 15	1,2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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